Agricultural and Forest Entomology (2003) **5**, 333–339

An improved multi-component sex attractant for trapping male western yellowstriped armyworm, *Spodoptera praefica* (Grote) (Lepidoptera: Noctuidae)

Peter J. Landolt, Connie Smithhisler, Todd Adams* and Richard S. Zack*

*Yakima Agricultural Research Laboratory, USDA-ARS, 5230 Konnowac Pass Road, Wapato, WA 98951 and *Department of Entomology, Washington State University, Pullman, WA 99164, United States*

Abstract

1 Chemical analyses of solvent extracts of pheromone glands of female western yellowstriped armyworm moths *Spodoptera praefica* (Grote) indicated the presence of (Z)-7-dodecenol (Z)-7-dodecenyl acetate (Z)-9-dodecenyl acetate (Z)-9-tetradecenyl acetate and (Z)-11-hexadecenyl acetate.

2 In field tests of combinations of these chemicals, small numbers of male *S. praefica* were captured in traps baited with (Z)-7-dodecenyl acetate. Numbers of males captured in traps were greatly increased in response to blends that included both (Z)-7-dodecenyl acetate with either (Z)-9-tetradecenyl acetate (Z)-9-dodecenyl acetate. The combination of (Z)-7-dodecenyl acetate and (Z)-9-tetradecenyl acetate provided the strongest sex attractant for use in trapping male *S. praefica*.

3 Males of the cabbage looper *Trichoplusia ni* (Hübner) were captured in traps baited with blends possessing (Z)-7-dodecenyl acetate, and were greatly reduced in traps baited with blends that included (Z)-7-dodecenol.

4 Multi-component blends that included (Z)-7-dodecenol attracted males of the alfalfa looper *Autographa californica* (Speyer).

5 Males of *Peridroma saucia* (Hübner) and *Mamestra configurata* Walker were captured in traps that included (Z)-9-tetradecenyl acetate with (Z)-11-hexadecenyl acetate.

6 These responses by other species of moths to *S. praefica* pheromone components and blends may still complicate the use of any lure for *S. praefica*.

Keywords Armyworm, attractant, lure, monitoring, pheromone, trapping.

Introduction

The western yellowstriped armyworm *Spodoptera praefica* (Grote) has a broad host range and is a pest of numerous agricultural crops (Blanchard & Conger, 1932), including sugarbeets (Lange, 1957), lentils (Halfhill, 1982) and alfalfa (Van den Bosch, 1950). This moth is widely distributed in western North America (Van den Bosch & Smith, 1955). The presence of *S. praefica* in agricultural crops is generally monitored by sweep-netting of larvae, although a sex-attractant for traps is commercially available for use in monitoring male *S. praefica* moths.

Correspondence: Peter J. Landolt. Tel.: +1 509 454 6551; fax: +1 509 454 5646; e-mail: landolt@yarl.ars.usda.gov

Currently, commercial lures for trapping *S. praefica* males release (Z)-7-dodecenyl acetate [(Z)-7-12:AC]. This compound is a relatively weak attractant for *S. praefica* and has the disadvantage of being strongly attractive to other common pest moth species. (Z)-7-Dodecenyl acetate is the major component of the sex pheromone of *Trichoplusia ni* (Berger, 1966), the alfalfa looper *Autographa californica* (Speyer) (Steck *et al.*, 1979a) and the soybean looper *Pseudoplusia includens* (Walker) (Tumlinson *et al.*, 1972). A stronger and more species-specific sex attractant for *S. praefica* might be more useful for monitoring male flights.

Sex pheromones that are produced by females and are attractive to males have been identified for a number of species of *Spodoptera*, and sex attractants that are likely sex pheromone components have been discovered for others (Mayer & McLaughlin, 1991). There are no published reports of the identification of sex pheromone compounds produced by female *S. praefica*. Birch (1977) captured males of *S. praefica* in traps baited with (Z)-7-12:AC for attracting the cabbage looper, *T. ni* Hübner. It appears likely that female *S. praefica* produce (Z)-7-12:AC as well as additional attractive compounds.

The objective of this study was to develop a stronger sex attractant for use in monitoring male *S. praefica*. Possible sex pheromone chemicals were identified from pheromone glands of female *S. praefica,* and combinations of those chemicals were then tested in a series of field trials as trap lures for males.

Materials and methods

General

Eggs were obtained from adult female *S. praefica* captured in a walk-in blacklight trap near Yakima, Washington, during April and June of 2001. Larvae were reared on a pinto bean based diet in 250 mL waxed paper cartons until near maturity. Maturing larvae were moved to $12 \times 25 \times 35$ cm plastic boxes with screened lids, in which 4 cm of soil was placed. Diet was placed on paper towels covering the soil and mature larvae pupated within the soil. Female pupae were placed in $25 \times 25 \times 25$ cm plastic screen cages in a controlled environment room (LD 14 : 10 h, 22 °C and 60% RH). Water was provided on cotton balls in a Petri dish on the cage floor and in an upside-down glass jar with a paper lid placed on the cage top. Pupae were moved from cages containing moths daily to provide batches of moths of discrete ages.

Two- to 5-day-old females were used for studies of pheromone gland extracts. During the eighth hour of the scotophase of the light cycle, when females appeared to be in a calling posture (wings spread and abdomen extended), everted female abdominal tips (with the pheromone gland) were excised with scissors and the tips were transferred with forceps to a glass microvial containing 50 µL of hexane. The hexane extract was then transferred to a second glass microvial. Three such samples were prepared, each with 2–5 abdominal tips. Before analysis, each sample was concentrated by evaporation to 2 µL. The sample was then analysed by gas chromatography-mass spectrometry (GC-MS).

Chemical analysis

GC-MS analyses performed done on a Hewlett Packard 6890 Plus gas chromatograph with a model 5973 electron impact mass selective detector (quadripole mass spectrometer for a detector). The gas chromatograph was equipped with an HP-1 MS (Hewlett-Packard Inc, Atlanta, GA, U.S.A.) fused silica capillary column (60 m in length, 0.25 mm inner diameter, 25 µm film thickness). Chromatography was conducted with a temperature program of 40 °C for 2 min, increasing by 20 °C/min to a final temperature of 200 °C. Total run time was 27 min. Similar analyses were performed using a DB wax fused silica capillary column (J & W Scientific, Folsum, CA), using a slower temperature ramp during the run, of 12 °C/min. Spectra of eluting peaks were matched to those in the Wiley 275 (Wiley & Sons Inc., Hoboken, New Jersey, U.S.A.) and NIST98 (National Institute of Standards and Technology, Gaithersburg, MD, U.S.A.) libraries of compounds to obtain preliminary structural assignments. These assignments were verified by comparison with mass spectra of known standards analysed using the same methods.

Structural identifications were also confirmed by comparing retention times of eluting peaks with known standards, using both types of columns. Retention times of compounds of interest in female extracts were compared with retention times of both the *cis*- (Z) and *trans*- (E) isomers of near (with two carbon bonds) positional isomers of the structure indicated in GC-MS analyses. Quantitative calculations were made by comparing peak areas for compounds in extracts with that of a synthetic standards. All synthetic standards were obtained from commercial sources.

Trapping experiments

Three field experiments were conducted to assess attractiveness of combinations of compounds identified in extracts of abdominal tips of female *S. praefica*. An additional field experiment was conducted to evaluate the relationship between the dose of a selected blend and male response. All experiments used Universal Moth Traps (Agrisense, Fresno, CA) with a 2.5×2.5 cm piece of Vaportape (Hercon Environmental Inc., Emigsville, PA) in the trap bucket to kill captured moths. Chemicals tested were formulated in red rubber septa (West Co, Lyonville, PA), which had been pre-extracted twice with methylene chloride in a tumbler, and were then air-dried before use. Septa treated with pheromone dosages were then air-dried in a fume hood for 24 h before use in experiments. Septa were placed in plastic baskets attached to the centre of the inside surface of the top of the trap. Traps were hung from stakes at a height of approximately 1 m, in a north–south orientation, along the borders of fields of alfalfa (*Medicago sativa*) in Yakima County, Washington. A randomized complete block design was used in all four tests, with treatments randomized within blocks each time that traps were serviced. Traps were serviced twice per week and lures were replaced after 2 weeks, when needed. Load amounts for chemicals in lures for the first three field tests are given in Table 1. Load ratios of chemicals in lures were based on analyses of female gland extracts.

The purpose of the first experiment was to determine if a blend of four chemicals found in female glands is more attractive to males than (Z)-7-12:AC. This field test preceded the identification of a fifth chemical in the female abdominal tip extract (Z)-9-dodecenyl acetate [(Z)-9-12:AC], and was considered at the time to be an evaluation of a complete blend. The four treatments were: (i) an unbaited trap as a negative control; (ii) (Z)-7-12:AC as a positive control; (iii) (Z)-7-12:AC (Z)-9-tetradecenyl acetate [(Z)-9-14:AC], (Z)-11-hexadecenyl acetate [(Z)-11-16:AC] and (Z)-11-dodecenol [(Z)-7-12:OH] as the four-component blend; and (iv) (Z)-7-12:AC, (Z)-9-14:AC and (Z)-11-16:AC as the three-component blend of the acetates. Traps were set

Table 1 Amounts of chemicals per septum used in trapping experiments

Compound	Loads (mg per septum) Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
Experiment 1: 15–25 June 2001							
(Z)-7-12:AC	0	1.0	0.83	0.80	–	–	–
(Z)-9-14:AC	0	0	0.02	0.02	–	–	–
(Z)-11-16:AC	0	0	0.15	0.13	–	–	–
(Z)-7-12:OH	0	0	0	0.05	–	–	–
Experiment 2: 19 June 3 July 2001							
(Z)-7-12:AC	0	0.83	0.83	0.83	0	–	–
(Z)-9-14:AC	0	0.02	0.02	0	0.02	–	–
(Z)-11-16:AC	0	0.12	0	0.15	0.15	–	–
Experiment 3: 22 July to 11 August 2002							
(Z)-7-12:AC	–	3	3	3	3	3	3
(Z)-9-12:AC	–	0	0.12	0	0.12	0.12	0.12
(Z)-9-14:AC	–	0	0	0.06	0.06	0.06	0.06
(Z)-11-16:AC	–	0	0	0	0	0.39	0.39
(Z)-7-12:OH	–	0	0	0	0	0	0.15

up in the field in five blocks on 15 June 2001 and were maintained for 1½ weeks. Within blocks, traps were 15–20 m apart, with a minimum of 50 m between trap blocks.

The purpose of the second experiment was to determine if the attraction of male *S. praefica* to the three-component blend comprised of (Z)-7-12:AC, (Z)-9-14:AC and (Z)-11-16:AC is due to activity of all three chemicals or to a subset of those three. The five treatments were: (i) an unbaited trap; (ii) (Z)-7-12:AC, (Z)-9-14:AC and (Z)-11–16:ACl; (iii) (Z)-7-12:AC and (Z)-11-16:AC; (iv) (Z)-7-12:AC and (Z)-9-14:AC; and (v) (Z)-9-14:AC, and (Z)-11-16:AC. Traps were set up in five treatment blocks on 19 June 2001 and were maintained for 2 weeks. Traps within blocks were 10 m apart, with a minimum of 50 m between blocks.

The purpose of the third experiment was to determine if the fifth chemical identified, (Z)-9-12:AC, is active as an attractant or coattractant for male *S. praefica,* when presented with (Z)-7-12:AC and selected blends of chemicals found in female gland extracts. Treatments were: (i) (Z)-7-12:AC; (ii) (Z)-7-12:AC and (Z)-9-12:AC; (iii) (Z)-7-12:AC and (Z)-9-14:AC; (iv) (Z)-7-12:AC, (Z)-9-12:AC and (Z)-9-14:AC; (v) (Z)-7-12:AC, (Z)-9-12:AC, (Z)-9-14:AC and (Z)-11-16:AC; and (vi) (Z)-7-12:AC, (Z)-9-12:AC, (Z)-9-14:AC, (Z)-11-16:AC and (Z)-7-12:OH. Traps were set up in five treatment blocks on 22 July 2002 and were maintained for 3 weeks. Traps within blocks were 12 m apart with a minimum distance of 50 m between blocks.

The purpose of the fourth experiment was to determine the relationship between captures of males in traps baited with the combination of (Z)-7-12:AC and (Z)-9-14:AC and the attractant dose applied to a septum. Dosages tested were 30, 100, 300, 1000, 3000 and 10 000 µg per septum, with (Z)-7-12:AC loaded at 95% and (Z)-9-14:AC at 5% of the total loaded. Traps were set up in five treatment blocks on 7 September 2001 and were maintained for 2 weeks. Traps within blocks were 20 m apart, with a minimum distance of 1 km between blocks.

Trap catch data for the first three experiments were subjected to an analysis of variance (ANOVA) and means were separated using a paired *t*-test. For the fourth experiment, a regression analysis was used to determine if there was a significant positive relationship between pheromone dose and captures of moths in traps. In addition, trap catch data for the 3 and 10 mg doses of the fourth test were compared by a paired *t*-test. StatMost software (DataMost, 1995) was used for all statistical analyses.

Results

Female gland extract analysis

GC-MS analyses of the extracts of female *S. praefica* abdominal tips revealed the consistent presence of five compounds considered to be possible pheromone components, based on general knowledge of structure of moth pheromones, including those of other *Spodoptera* spp. (Mayer & McLaughlin, 1991). These five compounds were identified as (Z)-7–12:OH, (Z)-7–12:AC, (Z)-9–12:AC, (Z)-9–14:AC and (Z)-11–16:AC.

Complete separation of all (Z) and (E) isomers was achieved using the polar (DB wax) column, with the exception of (Z)- and (E)-9-12:AC, which separated on both columns. All near positional isomers separated completely on both the polar and nonpolar (HP-1) column.

Amounts of each of these five compounds in female abdominal tip extracts are summarized in Table 2. (Z)-7-12:AC was the most abundant of these chemicals in the extracts. Lesser amounts on average of (Z)-7-12:OH, (Z)-9-12:AC, (Z)-9-14:AC and (Z)-11-16:AC were found in female extracts.

Table 2 Mean (± SE) amounts of pheromone components in extracts of female *Spodoptera praefica* abdominal tips ($n = 3$)

	(Z)-7-12:AC	(Z)-7-12:OH	(Z)-9-12:AC	(Z)-9-14:AC	(Z)-11-16:AC
ng/female	2.2 ± 0.7	0.24 ± 0.02	0.10 + 0.05	0.06 ± 0.02	0.46 ± 0.22
% of four-component blend	61.0	10.7	4.4	2.9	21.0

Field tests

In the first field test, significantly greater numbers of male *S. praefica* were captured in traps baited with the three-component blend made up of (Z)-7-12:AC, (Z)-9-14:AC and (Z)-11-16:AC, and the four-component blend made up of (Z)-7-12:AC, (Z)-9-14:AC, (Z)-11-16:AC and (Z)-7-12:OH, compared to unbaited traps and compared to traps baited with (Z)-7-12:AC alone (Table 3). Numbers of males captured in traps baited with (Z)-7-12:AC were not statistically greater than numbers in unbaited traps. The numbers of males trapped with the four-component blend were not statistically different than the numbers trapped with the three-component blend, which did not include (Z)-7-12:OH (Table 3).

Significant numbers of male *T. ni, A. californica and Mamestra configurata* Walker (bertha armyworm) moths were also captured in the first field test (Table 3). *Trichoplusia ni* were captured primarily in traps baited with (Z)-7-12:AC only and in traps baited with the three acetates, which included (Z)-7-12:AC. Numbers of *T. ni* captured in traps baited with the four-component blend that included (Z)-7-12:OH along with the three acetates were not significantly greater than numbers captured in unbaited traps and were lower than in traps baited with (Z)-7-12:AC or the three-component blend that included (Z)-7-12:AC (Table 3). Significant numbers of *A. californica* moths were captured only in traps baited with the four-component blend (Table 3). Significant numbers of *M. configurata* moths were captured in traps baited with the three- and four-component blends (Table 3).

In the second field test (Table 4), which evaluated the effects of omitting chemicals from the three-component blend comprised of (Z)-7-12:AC, (Z)-9-14:AC and (Z)-11-16:AC, the omission of either (Z)-9-14:AC or (Z)-7-12:AC rendered the traps unattractive to *S. praefica*, whereas the combination of (Z)-7-12:AC and (Z)-9-14:AC was just as attractive for this moth as the three-component blend.

Additionally, in the second field test, there were numerous nontarget moths captured (Table 4). Large numbers of male *M. configurata*, as well as numbers of male variegated cutworm moths, *Peridroma saucia* (Hübner) were captured in traps baited with the combination of (Z)-9-14:AC and (Z)-11-16:AC. *Mamestra configurata* males were also captured in traps baited with the three-component blend, but in greatly reduced numbers compared to traps baited with the combination of (Z)-9-14:AC and (Z)-11-16:AC. No male *P. saucia* were captured in traps baited with the three-component blend. Male cabbage looper moths, *T. ni*, were captured in traps baited with the three-component blend, and in traps baited with either of the two-component blends that included (Z)-7-12:AC (Table 4). No *A. californica* moths were captured in any of the traps during this test.

In the third field test (Table 5), a few male *S. praefica* were captured in traps baited with (Z)-7-12:AC. However, significantly more males were captured in traps baited with the combination of (Z)-7-12:AC and (Z)-9-12:AC, the combination of (Z)-7-12:AC and (Z)-9-14:AC and the multicomponent blends. Numbers of males in traps baited with (Z)-7-12:AC and (Z)-9-14:AC were significantly greater than numbers of males trapped with (Z)-7-12:AC and (Z)-9-12:AC. Numbers of males in traps baited with multicomponent blends were similar to numbers in traps baited with (Z)-7-12:AC and (Z)-9-14:AC, indicating no enhancement of attraction to that two-component combination by the inclusion of (Z)-9-12:AC, (Z)-11-16:AC and (Z)-7-12:OH.

In the third field test (Table 5), male *T. ni* moths were captured principally in traps baited with (Z)-7-12:AC, with much reduced numbers of moths, or no moths, in traps baited with other lures. Overall, numbers of *T. ni* moths captured in this test in 2002 were low compared to previous tests that were conducted in 2001. Male *M. configurata* were also captured in this experiment, in traps baited with the two multicomponent blends possessing both (Z)-9-14:AC and (Z)-11-16:AC.

Table 3 Mean (± SE) numbers of male moths captured in traps baited with blends of compounds from female *Spodoptera praefica* abdominal tip extracts

Blend	*Spodoptera praefica*	*Trichoplusia ni*	*Autographa californica*	*Mamestra configurata*
Unbaited trap	0.0 ± 0.0[a]	0.0 ± 0.0[a]	0.0 ± 0.0[a]	0.0 ± 0.0[a]
(Z)-7-12:AC	0.1 ± 0.1[a]	8.7 ± 3.2[b]	0.3 ± 0.3[a]	0.0 ± 0.0[a]
(Z)-7-12:AC, (Z)-9-14:AC and (Z)-11-16:AC	17.0 ± 3.6[b]	6.7 ± 2.6[b]	0.0 ± 0.0[a]	4.6 ± 3.3[b]
(Z)-7-12:AC, (Z)-9-14:AC, (Z)-11-16:AC and (Z)-7-12:OH	14.2 ± 3.4[b]	0.3 ± 0.2[a]	1.8 ± 0.6[b]	7.9 ± 4.3[b]

Means within a species column followed by the same superscript letter are not significantly different by a paired *t*-test (DataMost, 1995) ($P > 0.05$, d.f. = 14).

Table 4 Mean (± SE) numbers of male moths captured in traps baited with 2-component blends of the four compounds isolated from female *Spodoptera praefica* abdominal tip extracts

Blend	μg/septum	*Spodoptera praefica*	*Trichoplusia ni*	*Mamestra configurata*	*Peridroma saucia*
Unbaited trap	0	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
(Z)-7-12:AC (Z)-9-14:AC (Z)-11-16:AC	830 20 150	23.0 ± 3.1^{b}	2.6 ± 0.5^{b}	3.6 ± 1.5^{b}	0.0 ± 0.0^{a}
(Z)-7-12:AC (Z)-9-14:AC	830 20	21.6 ± 2.5^{b}	2.0 ± 0.5^{b}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
(Z)-7-12:AC (Z)-11-16:AC	830 150	0.1 ± 0.1^{a}	4.0 ± 0.8^{b}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}
(Z)-9-14:AC (Z)-11-16:AC	20 150	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	79.5 ± 14.0^{c}	4.3 ± 1.2^{b}

Means within a species column followed by the same superscript letter are not significantly different by a paired *t*-test (DataMost, 1995) ($P > 0.05$).

In the fourth test, comparing dosages of the two-component blend comprised of (Z)-7-12:AC and (Z)-9-14:AC, numbers of male *S. praefica* captured increased with dose, up to 3 mg ($r^2 = 0.95$; $P = 0.005$; $y = 1.7 + 0.0017x$). Numbers of *S. praefica* males captured in traps baited with 10 mg of pheromone were not significantly different than in traps baited with 3 mg of pheromone ($t = 1.34$; $P = 0.1$) (Fig. 1). Similar results were obtained for *T. ni*, with increasing numbers captured with pheromone dose, up to 3 mg ($r^2 = 0.00$; $P = 0.0003$; $y = 1.73 + 0.0082x$). Numbers of *T. ni* males captured in traps baited with 10 mg of pheromone were not significantly different than in traps baited with 3 mg of pheromone ($t = 0.03$; $P = 0.49$) (Fig. 1). No *M. configurata* or *P. saucia* were captured in this test. Numbers of *A. californica* captured ($n = 5$) were not suitable for statistical analysis (data for all treatments were not statistically greater than for unbaited traps).

Discussion

This work confirms a role of (Z)-7-12:AC as a sex attractant component for male *S. praefica*. Although we did not demonstrate captures of male *S. praefica* in traps baited with this chemical alone, it was shown to be a sex attractant for *S. praefica* by Birch (1977) who captured males during trapping experiments for *T. ni* moths. When (Z)-7-12:AC was not present in chemical blends, no male *S. praefica* were captured, indicating a critical role of (Z)-7-12:AC in sex attraction of this species. (Z)-7-Dodecenyl acetate was the compound present in greatest amounts in the extracts of female abdominal tips. This compound is also the major component of the sex pheromone of *T. ni* (Berger (1966), as well as other species in the noctuid subfamily *Plusiinae* (Tumlinson *et al.*, 1972; Steck *et al.*, 1979b).

Three of the compounds found in the extracts of female *S. praefica* abdominal tips have been found in other species

Table 5 Mean (± SE) numbers of male moths in traps baited with compounds identified from female *Spodoptera praefica* abdominal tip extracts

Blend	μg/septum	*Spodoptera praefica*	*Trichoplusia ni*	*Mamestra configurata*
(Z)-7-12:AC	3000	0.4 ± 0.1^{a}	1.4 ± 0.3^{b}	0.0 ± 0.0
(Z)-7-12:AC (Z)-9-14:AC	3000 60	48.3 ± 5.5^{c}	0.3 ± 0.1^{a}	0.0 ± 0.0
(Z)-7-12:AC (Z)-9-12:AC	3000 120	19.3 ± 3.2^{b}	0.0 ± 0.0^{a}	0.0 ± 0.0
(Z)-7-12:AC (Z)-9-12:AC (Z)-9-14:AC	3000 120 60	42.4 ± 6.1^{c}	0.2 ± 0.1^{a}	0.0 ± 0.0
(Z)-7-12:AC (Z)-9-12:AC (Z)-9-14:AC (Z)-11-16:AC	3000 120 60 390	41.9 ± 5.4^{c}	0.0 ± 0.0^{a}	1.4 ± 0.4
(Z)-7-12:AC (Z)-9-12:AC (Z)-9-14:AC (Z)-11-16:AC (Z)-7-12:OH	3000 120 60 390 150	40.6 ± 5.5	0.0 ± 0.0	1.0 ± 0.3

Means within a species column followed by the same superscript letter are not significantly different by a paired *t*-test (DataMost, 1995) ($P > 0.05$, d.f. = 26).

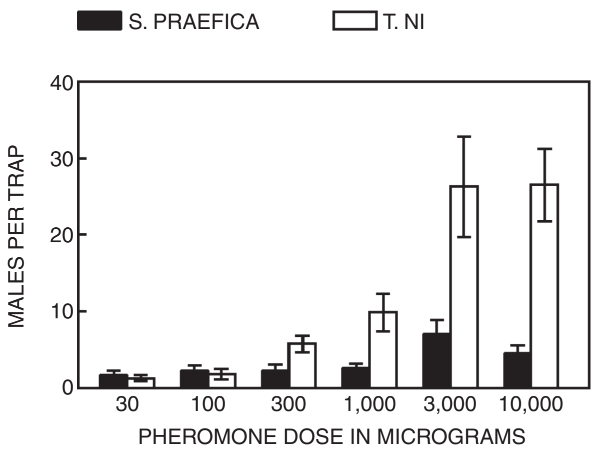

Figure 1 Mean (± SE) numbers of male *Spodoptera praefica* and *Trichoplusia ni* captured in traps baited with a 95 : 5 ratio of (Z)-7-12:AC and (Z)-9-14:AC at a range of microgram dosages in rubber septa.

of *Spodoptera* or are implicated as sex attractants for males of other species of *Spodoptera*. (Z)-7-Dodecenyl acetate and (Z)-9-14:AC have been found to be part of the female sex pheromone of *Spodoptera frugiperda* (J. E. Smith) (Sekul & Sparks, 1967; Tumlinson *et al*., 1986), and (Z)-9-14:AC and (Z)-11-16:AC are part of the pheromone of female *Spodoptera eridania* (Cramer) (Jacobson *et al*., 1970; Teal *et al*., 1985), among others.

In this study, two other compounds were present in extracts of female abdominal tips; (Z)-9-12:AC and (Z)-9-14:AC. These were demonstrated to be strong coattractants or synergists for male *S. praefica* when presented with (Z)-7-12:AC. Tests did not show any positive effect of (Z)-7–12:OH or (Z)-11-16:AC on male *S. praefica* attraction, despite their presence in the female abdominal tip extracts.

(Z)-7-Dodecenyl acetate, a sex attractant for male *S. praefica* (Birch, 1977) and the major component of the compounds found in female abdominal tip extracts, is a strong attractant for male *T. ni* (Berger (1966); Saario *et al*., 1970). In 2001, large numbers of male *T. ni* were captured in traps baited with many of the blends that included (Z)-7-12:AC. The presence of (Z)-7-12:OH in blends did provide some specificity to the sex attraction for *S. praefica* by nearly eliminating captures of male *T. ni* in traps although not significantly reducing numbers of *S. praefica* trapped. Our results with *T. ni* are in agreement with those reported by Tumlinson *et al*. (1972), indicating that (Z)-7-12:OH is a potent inhibitor of male *T. ni* attraction to (Z)-7-12:AC.

The practical advantage of the inhibition of male *T. ni* response to the *S. praefica* pheromone by adding (Z)-7-12:OH to the blend was countered by a significant positive response in 2001 of *A. californica* to a blend containing the same compound. This response was due presumably to the combination of (Z)-7-12:AC and Z7-12:OH in that blend. Steck *et al*. (1979a, 1979b) trapped male *A. californica* with chemical blends that included (Z)-7-12:AC and (Z)-7-12:OH. The lack of a response by *A. californica* to the blend that included these two compounds during 2002 (third test) was possibly due to a lack of a suitable population in the field at that time. A species-specific lure for *S. praefica* would be of benefit to growers, scouts and consultants, to reduce confusion and labour resulting from the capture multiple species of moths when monitoring only one species.

The combination of (Z)-9-14:AC and (Z)-11-16:AC attracted numbers of both *M. configurata* and *P. saucia*, although attracting no male *S. praefica*. Underhill *et al*. (1977) reported these two chemicals as the sex attractant pheromone of *M. configurata* and Byers & Struble (1987) trapped *M. configurata* with mixtures including (Z)-9-14:AC and (Z)-11-16:AC. Struble *et al*. (1976) trapped *P. saucia* with the same two compounds. The addition to blends of (Z)-7-12:AC, a compound critical to sex attraction of *S. praefica*, appeared to strongly curtail the responses of *M. configurata* and *P. saucia* males to the combination of (Z)-9-14:AC and (Z)-11-16:AC.

For practical purposes, the combination of (Z)-7-12:AC and (Z)-9-14:AC provided the simplest combination of chemicals for strong attraction of male *S. praefica* to traps. Our results indicated a large increase in numbers of males trapped with this combination of chemicals compared to the use of (Z)-7-12:AC alone, which has been used to date for monitoring *S. praefica* male flight. An optimum dosage of 3 mg was indicated for use of the two component blend of (Z)-7-12:AC and (Z)-9-14:AC. Additional studies must be performed to determine if this lure can be improved further by altering the ratios of various chemicals found in the female gland, and to evaluate other variables important to its use as a monitoring agent, such as lure longevity, lure placement and trap designs. Furthermore, it is recognized that the presence of pheromone-like chemicals in the female abdominal tip extracts is only an indication of possible pheromonal activity, and is not proof that the chemicals are indeed released as a pheromone signal by the female moth. Volatile collections need to be conducted to demonstrate release, and bioassays of chemicals need to be conducted to accurately characterize the female-released sex pheromone of *S. praefica*.

Acknowledgements

Technical assistance was provided by J. A. Brumley, J. Beauchene, D. L. Greene and D. Lovelace. We thank T. Harris, D. Martinez, P. Smith and C. Martin for use of their fields. This work was supported in part by a grant from the US Environmental Protection Agency.

References

Berger, R.S. (1966) Isolation, identification, and synthesis of the sex attractant of the cabbage looper, *Trichoplusia ni*. *Annals of Entomological Society of America*, **59**, 767–771.

Birch, M.C. (1977) Response of both sexes of *Trichoplusia ni* (Lepidoptera: Noctuidae) to virgin females and to synthetic pheromone. *Ecological Entomology*, **2**, 99–104.

Blanchard, R.S. & Conger, C.B. (1932) Notes on *Prodenia praefica* Grote. *Journal of Economic Entomology*, **25**, 1059–1070.

Byers, J.R. & Struble, D.L. (1987) Monitoring population levels of eight species of noctuids with sex-attractant traps in southern Alberta, 1978–1983: specificity of attractants and effects of target species abundance. *Canadian Entomology*, **119**, 541–556.

DataMost (1995) *Statmost Statistical Analysis and Graphics*. DataMost Corporation, Salt Lake, Utah.

Halfhill, J.E. (1982) Evaluation of western yellowstriped army-worm (Lepidoptera: Noctuidae) as a pest of lentils. *Journal of Economic Entomology*, **75**, 733–735.

Jacobson, M.R.E., Redfern, W.A., Jones & Aldridge, M.H. (1970) Sex pheromones of the southern armyworm moth: isolation, identification, and synthesis. *Science*, **170**, 542–543.

Lange, H.W. (1957) Another outbreak of the western yellowstriped armyworm? *Spreckles Sugarbeet Bulletin*, **21**, 22–23.

Mayer, M.S. & McLaughlin, J.R. (1991) *Handbook of Insect Pheromones and Sex Attractants*. CRC Press, Boca Raton, FL.

Saario, C.A., Shorey, H.H. & Gaston, L.K. (1970) Sex pheromones of noctuid moths. XIX. Effect of environmental and seasonal factors on captures of males of *Trichoplusia ni* in pheromone baited traps. *Annals of Entomological Society of America*, **63**, 667–672.

Sekul, A.A. & Sparks, A. (1967) Sex pheromone of the fall armyworm: isolation, identification, and synthesis. *Journal of Economic Entomology*, **60**, 1270–1272.

Steck, W., Underhill, E.W., Chisholm, M.D. & Gerber, H.S. (1979a) Sex attractant for male alfalfa looper moths, *Autographa californica*. *Environmental Entomology*, **8**, 373–375.

Steck, W.F., Chisholm, M.D., Bailey, B.K. & Underhill, E.W. (1979b) Moth sex attractants found by systematic field testing of 3-component acetate-aldehyde candidate lures. *Canadian Entomologist*, **111**, 1263–1269.

Struble, D.L., Swailes, G.E., Steck, W.F., Underhill, E.W. & Chisholm, M.D. (1976) A sex attractant for males of variegated cutworm, *Peridroma saucia*. *Environmental Entomology*, **5**, 988–990.

Teal, P.E.A., Mitchell, E.R., Tumlinson, J.H., Heath, R.R. & Sugie, H. (1985) Identification of sex pheromone components released by the southern armyworm, *Spodoptera eridania* (Cramer). *Journal of Chemical Ecology*, **11**, 717–726.

Tumlinson, J.H., Mitchell, E.R., Browner, S.M. & Lindquist, D.A. (1972) A sex pheromone for the soybean looper. *Environmental Entomology*, **1**, 466–468.

Tumlinson, J.H., Mitchell, E.R., Teal, P.E.A., Heath, R.R. & Mengelkoch, L.J. (1986) Sex pheromone of the fall armyworm, *Spodoptera frugiperda* (Smith). Identification of components critical to attraction in the field. *Journal of Chemical Ecology*, **12**, 1909–1926.

Underhill, E.W., Steck, W.F. & Chisholm, M.D. (1977) A sex pheromone mixture of the Bertha armyworm moth, *Mamestra configurata*: (Z)-9-tetradecen-1-ol acetate, (Z)-11-hexadecen-1-ol acetate. *Canadian Entomologist*, **109**, 1335–1340.

Van den Bosch, R. (1950) Bionomics of *Prodenia praefica*. *California*. PhD Dissertation. University of California. Berkeley.

Van den Bosch, R. & Smith, R.F. (1955) A taxonomic and distributional study of the species of *Prodenia* occurring in California. *Pan-Pac Entomology*, **31**, 21–28.

Accepted 13 August 2003